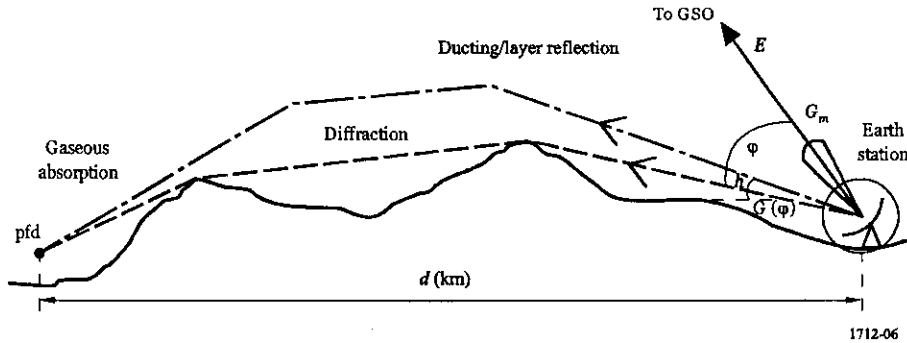


FIGURE 6  
Loss on interference path



The pfd at the low-water mark or land border may be calculated by equation (1):

$$\text{pfd} = E - G_m + G(\phi) - L - 10 \log (\lambda^2/4\pi) \quad \text{dB(W/m}^2\text{)} \quad (1)$$

where:

$L$ : path-loss between isotropic antennas exceeded for all but 1% of the time (dB)

$\lambda$ : wavelength (m)

At the mid-band frequency of 13.875 MHz,  $\lambda = 0.02162$  m, so  $10 \log (\lambda^2/4\pi) = -44.29$ . Then, to meet the required pfd limit, rearranging equation (1) gives:

$$L = E - (G_m - G(\phi)) + 159.29 \quad \text{dB} \quad (2)$$

If the factors in the right hand side of equation (2) could be reduced to constants, the areas in which an earth station would meet the pfd limit would be indicated by contours of constant  $L$ .

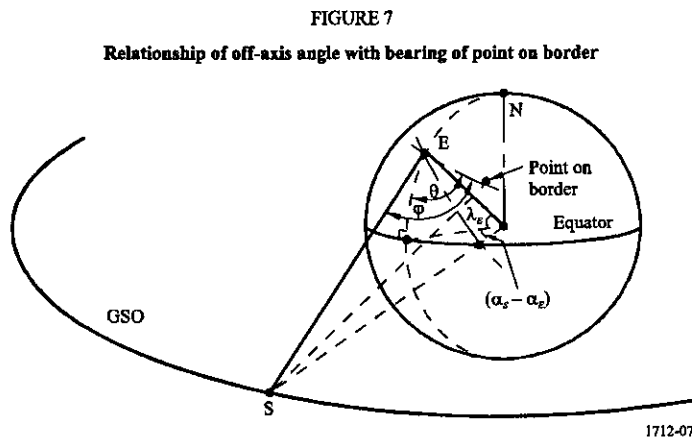
The factor  $(G_m - G(\phi))$  is the discrimination afforded by the earth station transmit antenna pattern in the direction of the interference path, and it depends on the antenna diameter and radiation pattern and on the off-axis angle  $\phi$ . For the radiation pattern, it is appropriate to employ the algorithms in Recommendation ITU-R S.580 for the side lobes, and to add a main-beam with a square-law roll-off (i.e.  $G(\phi) = G_m - 12(\phi/\phi_{3dB})^2$ ) and a peak gain,  $G_m$ , corresponding to an illumination efficiency of 65% (i.e.  $G_m = 10 \log [(0.65) (\pi D/\lambda)^2]$  where  $D$  is the antenna diameter (m), and  $\phi_{3dB} = 70\lambda/D$ ). Thus, for any given earth station e.i.r.p. and antenna diameter, the value of  $L$  required to just meet the pfd limit may be calculated if the relevant value of  $\phi$  is known.

The earth station height above the terrain,  $h_E$ , should be determined by the concerned administration according to the type of deployment intended. For example, the contours shown later in this Annex were computed for  $h_E = 11.2$  m. This level implies highly-mounted terminals. If the earth station were contemplated for mounting on single-story flat roof structures (such as a gas station), 5 to 6 m would be appropriate. Caution should be used to avoid mounting earth stations above the height used to construct the contours so as to avoid exceeding the permitted pfd at the low-water mark. For mounting on taller buildings in an urban environment, even higher values for  $h_E$  would be necessary. In an urban environment, off-axis earth station paths in such locations may be blocked by considerable clutter. In any case, such level of detail

goes beyond the intent of Method 2. This method should be based on "typical" deployments rather than extreme cases.

### 3.2 Earth station off-axis angle for maximum pfd at low-water mark or land border

It can be seen in Fig. 5 that the off-axis angle depends on the direction toward the low-water mark or land border, and on the azimuth,  $a$ , and elevation,  $e$ , angles in which the earth station antenna is pointing. From Fig. 6 it can be seen that, to a small extent,  $\phi$  depends also on the elevation angle,  $h$ , of the local horizon. From the ITU-R reference patterns it is seen that, for relatively small off-axis angles the antenna discrimination increases fairly rapidly (proportionally to  $25 \log(\phi)$ ), but for larger angles it tends to flatten out. The direction of the lowest-loss path toward the low-water mark or border depends partly on the geography of the terrain between the border and the earth station – i.e. there is a tendency for the lowest-loss path to lie in an azimuth direction near to that in which the distance to the border is shortest, and partly on the nature of the terrain (in hilly terrain the lowest-loss path may not coincide with the shortest path). If the direction of the shortest path is near to the azimuth pointing direction of the earth station antenna and the antenna elevation angle is low then, even if the shortest path is not the lowest-loss path, the highest pfd may be produced because the effect of the antenna discrimination outweighs the effect of the terrain. However, since the azimuth bearing,  $\theta$ , of the lowest-loss path to the border may be anything from  $0$  to  $\pm 180^\circ$  with respect to due-South, it is instructive to review how  $\phi$  varies with  $\theta$  for different combinations of  $a$  and  $e$ . The values of  $a$  and  $e$  themselves depend on the latitude of the earth station,  $\lambda_E$ , and on its longitude,  $\alpha_E$ , relative to longitude,  $\alpha_S$ , of the satellite to which it is transmitting.



From the geometry of Fig. 7 the off-axis angle  $\phi$  (when  $h = 0^\circ$ ) was calculated for values of the bearing  $\theta$  in  $5^\circ$  steps from  $-180^\circ$  to  $+180^\circ$ , for earth stations at various different latitudes, and in each case for a range of differences in longitude between earth station E and its satellite S, thus spanning most practicable situations. Considering earth stations in general, all bearings for the lowest-loss path to the low-

water mark or the land border are equally likely. Hence it was possible to convert the data thus obtained into cumulative probability distributions of  $\phi$ . By adjusting these results to allow for  $h = +3^\circ$  it was found that in the case of earth stations at  $\pm 10^\circ$  latitude, for example,  $\phi$  exceeds  $48^\circ$  for 96% of azimuth bearings. Similarly, for earth stations at  $\pm 35^\circ$  latitude  $\phi$  exceeds  $48^\circ$  for 92% of azimuth bearings, and for earth stations at  $\pm 60^\circ$  latitude  $\phi$  exceeds  $48^\circ$  for 91% of azimuth bearings. Since  $48^\circ$  is the off-axis angle at which the gain patterns in Recommendation ITU-R S.580 flatten off, the earth station antenna discrimination may thus be regarded as constant in 91% to 96% of cases. The value of that discrimination depends on the antenna diameter, and is as given in Table 1 for antennas with 65% efficiency:

TABLE 1

Maximum antenna discrimination from Recommendation ITU-R S.580

Antenna diameter (m)	1.2	1.5	1.8	2.1	2.6	3.1	4.5
Discrimination ( $G_m - G(\phi)$ ) for $\phi \geq 48^\circ$ (dB)	53.0	54.9	56.5	57.8	59.7	61.2	64.4

From the results of the calculations described in the foregoing paragraph it was found that the minimum values of off-axis angle occur for values of  $\theta$  not far from the difference in longitude between the satellite and the earth station. Therefore, although it is "safe" to employ the present methodology for the great majority of cases, if an earth station site is on or close to the contour relevant to its e.i.r.p. and antenna size and there is reason to believe that the lowest loss path to the low-water mark or land border (e.g. the path to the nearest point is in approximately the azimuth direction of the satellite), and the elevation angle to the satellite is less than  $(48^\circ + h)$ , it will be necessary to make an individual calculation of the pfd rather than relying on the contour. However, this will only be necessary in a small minority of cases, depending mainly on the latitude of the country in which the FSS earth station is intended to be deployed. In those instances where the FSS earth stations operate above a certain elevation angle (e.g. above  $48^\circ + h$  for Recommendation ITU-R S.580 antenna pattern) the e.i.r.p. density towards the horizon will be constant for all azimuths. In such cases, the contours corresponding to the required distance can be computed as a function of input power into the antenna and are independent of the antenna size.

In the exceptional cases where an earth station site is within but close to the contour relevant to the e.i.r.p. and antenna size concerned, the elevation angle is less than  $51^\circ$  (i.e.  $48^\circ + 3^\circ$ ), and the azimuth bearing toward the satellite is near to the bearing of the lowest-loss path to the border, the off-axis angle,  $\phi$  should be calculated from the expression  $\phi = \cos^{-1}[\cos(\theta - a) \cdot \cos(e) \cdot \cos(h) + \sin(e) \cdot \sin(h)]$  (degrees). If the result is less than  $48^\circ$ , then the earth station might exceed the pfd limit at the border by the difference between the off-axis gain derived according to Recommendation ITU-R S.580 for that particular off-axis angle and  $-10$  dBi, if it was exactly on the contour, or less if inside the contour. This excess could be removed by either relocating the earth station to a site further inside the contour, reducing the e.i.r.p., adding local site-shielding, or a combination of some or all of these factors, depending on circumstances. In the worst (and very unlikely) case where  $e = 10^\circ$ ,  $h = 3^\circ$  and  $\theta = a$ , up to 17.9 dB of such mitigation would be required.

### 3.3 Considerations concerning earth station e.i.r.p. (E)

The remaining factor to be resolved in equation (2) is E. To ensure that any contours produced will embrace the majority of earth station e.i.r.p. levels likely to be transmitted by small-dish earth stations in the band 13.75-14 GHz, a statistical analysis was made of the replies to the Questionnaire in Administrative Circular CA/90 issued by the Radiocommunication Bureau on behalf of Joint Task Group 4-7-8 in 2002. Those replies were based on current practice in the band 14-14.5 GHz, but it is reasonable to anticipate that a similar pattern of use will now develop in the 13.75-14 GHz band. The replies revealed a preponderance of antennas of particular diameters within the range of interest, and these are indicated in Table 1. It was thus convenient to analyse the data in four ranges of antenna diameter, namely 1.2-1.5 m, 1.5-2.1 m, 2.1-3.1 m and 3.1-4.5 m, and the results were obtained in the form of cumulative distribution functions (CDFs) showing the percentage of earth stations as a function of maximum e.i.r.p./10 MHz.

From these CDFs it was deduced that the range of E to be considered here is from 83 dBW, which would cover 90% of the earth stations with the largest antenna diameters (below 4.5 m), and 35 dBW, which would cover only 30% of the earth stations with the smallest diameter antennas (above 1.2 m).

### 3.4 Basis for contours

The information summarized in § 2 and 3 enabled equation (2) to be used to identify discrete values of  $L$ , the path loss required to be exceeded for 99% of the time in order to meet the pfd limit, for a number of suitable cases. The derivation of contours corresponding to these values of  $L$  would then define the area in a country where earth stations not exceeding the relevant e.i.r.p. levels could be deployed, without interference mitigation or individual site analysis, and the pfd limit would automatically be met everywhere on the low-water mark or land border. By trial-and-error it was found that five contours would be appropriate in typical cases, and the basis for them is summarized in Table 2 that was compiled from equation (2) and the information referred to in § 3.2 and 3.3.

TABLE 2

Earth station antenna diameter and e.i.r.p. combinations for suitable contours

Contour reference	Antenna diameter range ( $D$ m) and ( $G_m - G(\varphi) \leq 48^\circ \leq \varphi \leq 180^\circ$ ) for minimum size in the range				Path loss, $L$ , exceeded for 99% of time (dB)
	$1.2 \leq D < 1.5$ $G_m - G(\varphi) = 53.0$ dB	$1.5 \leq D < 2.1$ $G_m - G(\varphi) = 54.9$ dB	$2.1 \leq D < 3.1$ $G_m - G(\varphi) = 57.8$ dB	$3.1 \leq D < 4.5$ $G_m - G(\varphi) = 61.2$ dB	
	E (dB(W/10 MHz))	E (dB(W/10 MHz))	E (dB(W/10 MHz))	E (dB(W/10 MHz))	
A	$\leq 36.5$	$\leq 38.4$	$\leq 41.3$	$\leq 44.7$	142.8
B	$\leq 45.5$	$\leq 47.4$	$\leq 50.3$	$\leq 53.7$	151.8
C	$\leq 54.5$	$\leq 56.4$	$\leq 59.3$	$\leq 62.7$	160.8
D	$\leq 63.5$	$\leq 65.4$	$\leq 68.3$	$\leq 71.7$	169.8

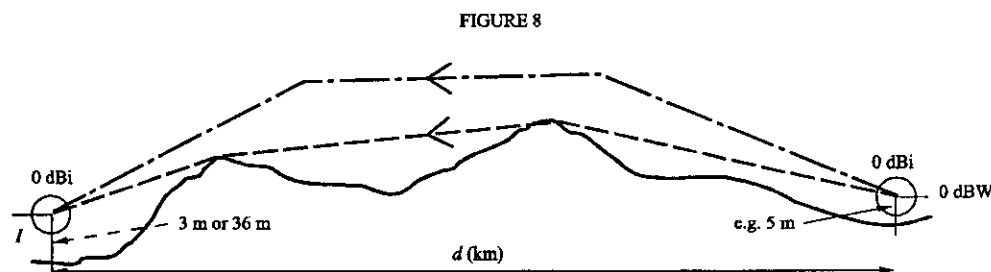
F	$\leq 72.5$	$\leq 74.4$	$\leq 77.3$	$\leq 80.7$	178.8
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Thus, for example, earth stations with antennas of diameter between 2.1 m and 3.1 m and transmitting e.i.r.p.s of up to 59.3 dB(W/10 MHz) would meet the pfd limit at the low-water mark or land border, without interference mitigation, if they were located anywhere further from the low-water mark or land border than a contour defined by a path loss of 160.8 dB not exceeded for more than 1% of the time (contour reference C). Using the information summarized in § 2 and 3 it is possible to interpolate between contours based on these five path losses. Furthermore, since the values of  $L$  in adjacent rows are separated by 9 dB, the benefit of adding 9, 18 or 27 dB of site-shielding local to an earth station may be deduced from the Table; taking the example in the previous paragraph, the addition of 9 dB of site-shielding would enable the earth station either to be deployed up to contour B, or to remain within contour C but increase its e.i.r.p. up to 68.3 dB(W/10 MHz).

### 3.5 Computation of contours

Losses on an overland path may be calculated by adding (in parallel) the effects of free-space propagation, gaseous absorption, diffraction, tropospheric ducting and layer reflection, using the data and algorithms in Recommendation ITU-R P.452. For a given earth station location, to ensure that the pfd limit is not exceeded it is necessary to find the lowest-loss line to the low-water mark or land border. For flat terrain this will be the line between the earth station and the nearest point on the low-water mark or neighbouring country's land border (as called "border" in this section), but that will not always be the case where the intervening terrain is either moderately or very hilly. Thus a software database containing the heights above sea level over the whole of the area concerned, with a resolution as fine as practicable, is required for the present exercise. The following technique may be used here.

Taking the terrain profile in Fig. 6 as an example, the pfd measurement point may be replaced by a receiver fed by an isotropic receiving antenna, and the FSS transmitting earth station may be replaced by an isotropic transmitting antenna – as in Fig. 8:

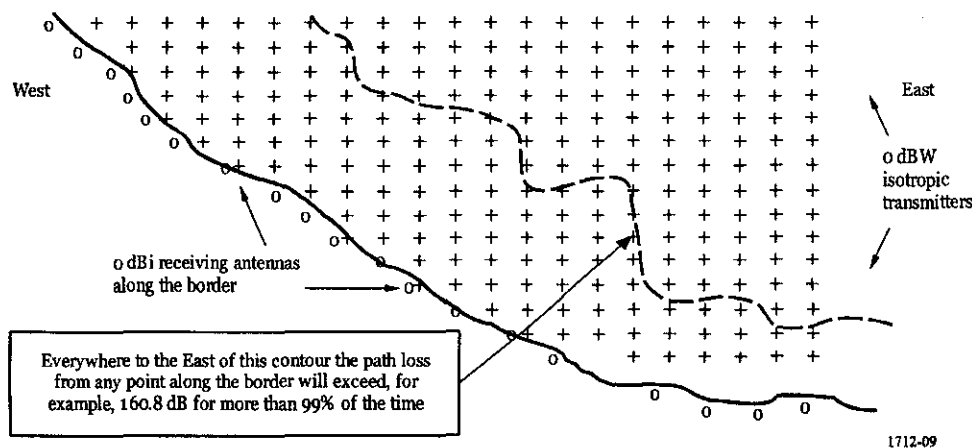


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Then the level of the received signal  $I$  is given by  $I = 0 + 0 - L + 0$  dBW. In other words, the level of  $I$  (dBW) is numerically equal to minus the value of the path loss  $L$  (dB), and this is so regardless of the bearing of the receiver with respect to the transmitter. For the present purpose  $I$  should be computed in the manner described in Recommendation ITU-R P.452-11, for 1% of time.

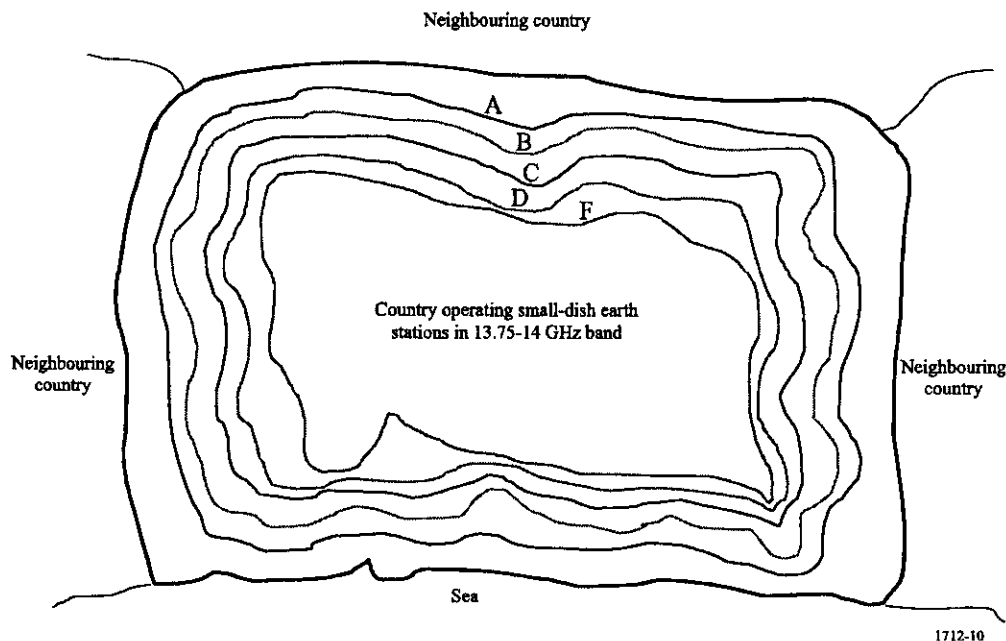
A software model should be constructed, incorporating a terrain database for the country or area of interest, and containing isotropic receiving terminals at appropriately small intervals along the low-water mark or land border. A grid of equally-spaced 0 dBW isotropic radiators should be added covering the entire country or area concerned. Then the contribution to  $I$  at each and every receiver, generated by each and every transmitter should be computed, using Recommendation ITU-R P.452-11 techniques to evaluate the loss exceeded for all but 1% of the time, and all the values for each receiver should be separately stored. The software should be arranged to identify the maximum individual contribution to  $I$  for each receiver, and also the individual transmitter in the grid responsible for it<sup>2</sup>. Then, by selecting the transmitters for which the maximum  $I$  contribution is closest to minus the value of  $L$  required, a contour may be constructed by drawing a line between those transmitters. For improved accuracy it is possible to use linear interpolation between pairs of transmitters corresponding to the maximum  $I$  contributions that are the closest above and below the target value, as illustrated in Fig. 9.

FIGURE 9



<sup>2</sup> This latter feature enables the lowest-loss path to the border for any individual point on a contour to be identified in those cases where there is doubt that the pfd limit would be met. From the terrain profile of that path,  $h$  may be found.

FIGURE 10



In the area between a contour and the low-water mark or land border it may be possible to operate small-dish earth stations if interference mitigation techniques such as restriction to lower-e.i.r.p. carriers and or local site-shielding are applied, but that would have to be determined on a case-by-case basis. In each such case the present methodology could be used to determine the lowest-loss path from the site to the low-water mark or land border, and the loss of that path, and that would determine the degree of mitigation required.

It is worth noting that, for particular cases in which small-dish earth stations are planned always to operate to a single location in the GSO, system-specific contours may be computed by adapting the methodology so that each (+) point in the grid in Fig. 9 includes an antenna pointing toward that location.

### 3.6 Examples of applying the methodology described in § 3.1 to 3.5

Using a proprietary software package incorporating a global terrain database having a horizontal resolution of 1 km and a vertical resolution of 1 m, the foregoing methodology was employed to construct models of eight different areas, with the aim of covering a variety of country sizes, types of terrain and climate. For each receive point on a coast (in these examples the low-water mark was set at the coast) the antenna height was set at 36 m, and for receive points on land borders the height was set at 3 m. In order to produce contours each covering the whole range of earth station antenna sizes it was necessary to select a single height for all the transmit points. A transmit height of 11.2 m was chosen for the present computations. All the areas selected are in well-populated parts of the world. The details are listed in Table 3.

TABLE 3  
Characteristics of software models constructed

Geographical area	Size of country	Climate ( $\Delta N$ ) <sup>(1)</sup>	Type of terrain	Receiver spacing (km)	Transmitter grid interval (km)	No. of paths computed <sup>(2)</sup>
Mississippi Basin	Large	Temperate (51)	Non-hilly	10	10	455 224
Southern England	Medium	Temperate (45)	Medium	10	5	83 582
Southern Turkey	Medium	Temperate (45)	Hilly	10	10	300 000
North-West India	Large	Tropical (60)	Non-hilly	10	10	702 450
Central Mexico	Medium	Tropical (60)	Hilly	10	10	691 114
Cuba	Long, thin island	Tropical (55)	Medium-to-non-hilly	10	10	346 626
Java	Long, thin island	Tropical (60)	Medium-to-hilly	10	10	288 144
Cyprus	Small island	Temperate (50)	Medium	6	4	252 960

<sup>(1)</sup>  $\Delta N$  is the average radio-refractive index lapse-rate through the lowest 1 km of the atmosphere, which depends significantly on climate and is needed for the path loss calculation method of Recommendation ITU-R P.452.

<sup>(2)</sup> i.e. Number of transmit points in grid multiplied by number of receive points on border.

In order to obtain complete contours as illustrated in Fig. 10 it is necessary to model the whole border of a country, which for large countries would require the inclusion of large numbers of transmit and receive points and correspondingly long construction and computing times. Furthermore, the ability to print on a sheet very much larger than A4 size would be needed in order to use such complete contours with accuracy. Ideally a terrain database of higher resolution than the one used here would be employed, and to obtain the benefit of it the spacing between adjacent transmit points and between adjacent receive points should be smaller, which would further increase the modelling and computing times. In view of these factors it is probably convenient for an administration to model parts of its country separately, especially if the most accurate contours practicable are required.

Examples from the results obtained for the areas listed in Table 3 are shown in Figs. 11, 12 and 13, in which it can be seen that contours corresponding to the earth station antenna diameter and e.i.r.p. combinations defined in Table 2 are shown. For convenience the contours are labelled A, B, C, D and F as in Table 2 and Fig. 10, and they are displayed in contrasting colours to aid legibility.

Overall the full set of results were found to adequately demonstrate the effectiveness of the methodology in this Annex in determining where the great majority of FSS



earth stations using the band 13.75-14 GHz could be placed without exceeding the pfd limits in RR No. 5.502. However, it would be preferable for FSS operators in the countries concerned to use more detailed maps, a higher resolution terrain database and a greater density of transmit and receive points per model, for the assessment of sites near the contours.

**Fig. 11, Mississippi Basin, United States of America**

As expected, the contours for the lowest e.i.r.p.s are nearest the low-water mark while those for the highest e.i.r.p.s are furthest from the low-water mark. The mean distances from the low-water mark vary from about 30 km for contour A to about 130 km for contour F, and thus the zones between the contours and the low-water mark represent fairly large areas in which earth stations transmitting the e.i.r.p.s indicated, and without site-shielding or another interference-mitigation technique, could not legally use the 13.75-14 GHz band. This arises because the terrain in the Mississippi Basin is relatively flat and hence diffraction losses are relatively low. Fortunately the United States of America is a large country, so the proportion of its land mass in which FSS use of the band would have constraints is fairly modest.

**Fig. 12, Central Mexico**

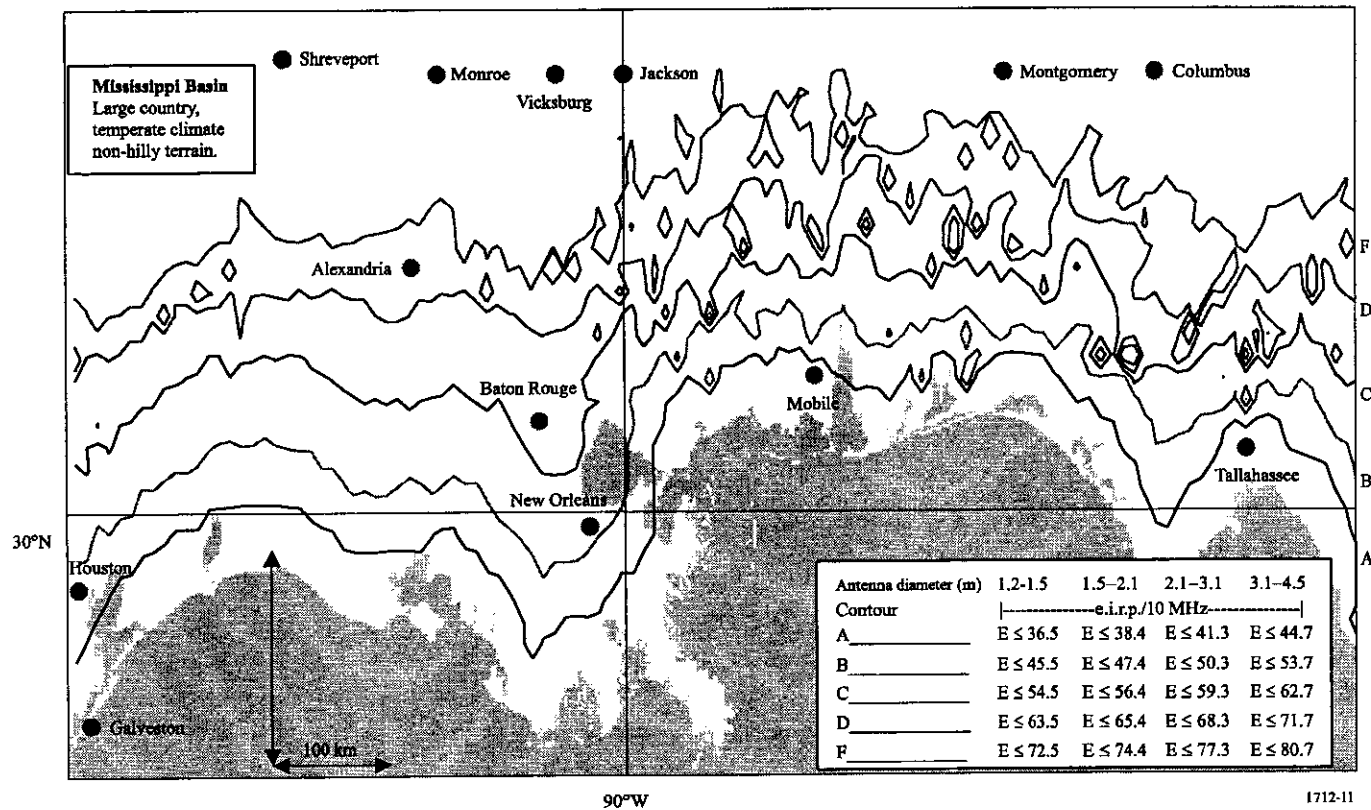
The fact that Mexico is a mountainous country and is mostly well above sea level allows earth stations to be operated in the great majority of its territory without exceeding the pfd limit at its borders. The terrain near the south coast is such that there is little difference between the five contours, and only earth stations within an average of about 20 km of the sea would face restrictions in the 13.75-14 GHz band. Near the north coast constraints would be faced by earth stations over a rather larger area owing to some relatively low land around river valleys, but even there the average distances between contour and sea are less than in North West India or the Mississippi Basin, despite the tropical climate.

**Fig. 13, Cuba (Caribbean)**

Clearly, although contour A would cover most of Cuba, contours B, C, D and F cover only small or very small proportions of this thin island, and thus one or more of the interference mitigation techniques described in Annex 4 would be needed unless it should be deemed satisfactory for only low e.i.r.p. carriers to be operated (see Table 2). Accordingly the computation was adapted to provide an additional contour G, which corresponds to a minimum path loss to the low-water mark for all but 1% of the time of 138 dB, i.e. about 5 dB less than in the case of contour A. It follows that if 5 dB of interference mitigation can be applied at an earth station conforming to the first row in Table 2, the pfd limit will be met by that station if it is located anywhere inside contour G. Similarly, if 14 dB of mitigation can be applied to an earth station conforming to the second row in Table 2, then that earth station may be located anywhere within contour G. And 23 dB of mitigation for the third row, etc. Furthermore, the application of 9 dB of interference mitigation to any earth station conforming to one of the rows in Table 2 would enable it to be located within the contour defined by the next row above in the Table.

FIGURE 11

Contours beyond which earth stations without shielding would  
meet  $\text{pfd} = -115 \text{ dB(W/(m}^2 \cdot 10 \text{ MHz))}$  at coast for 99% of time



**Contours beyond which earth stations without shielding would meet  
pfd = -115 dB(W/(m<sup>2</sup> · 10 MHz)) at coast for 99% of time**

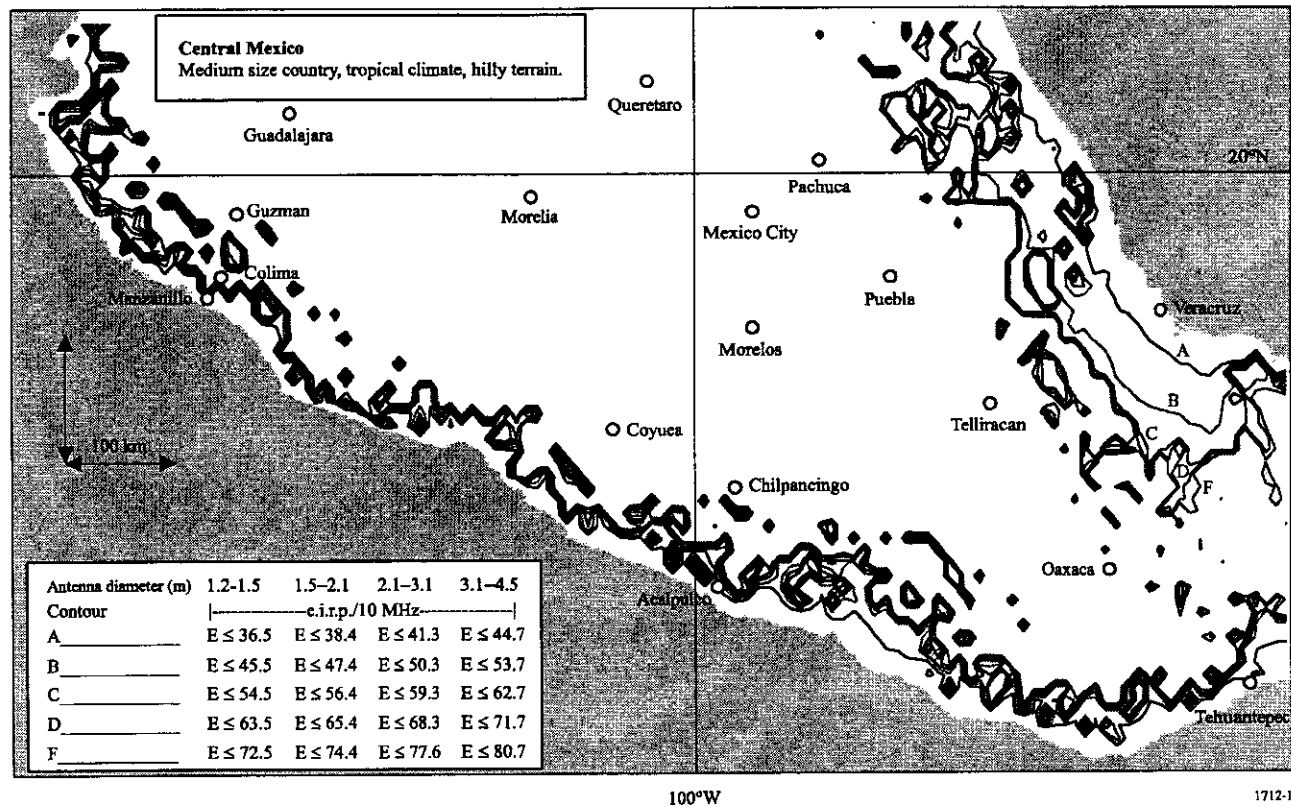
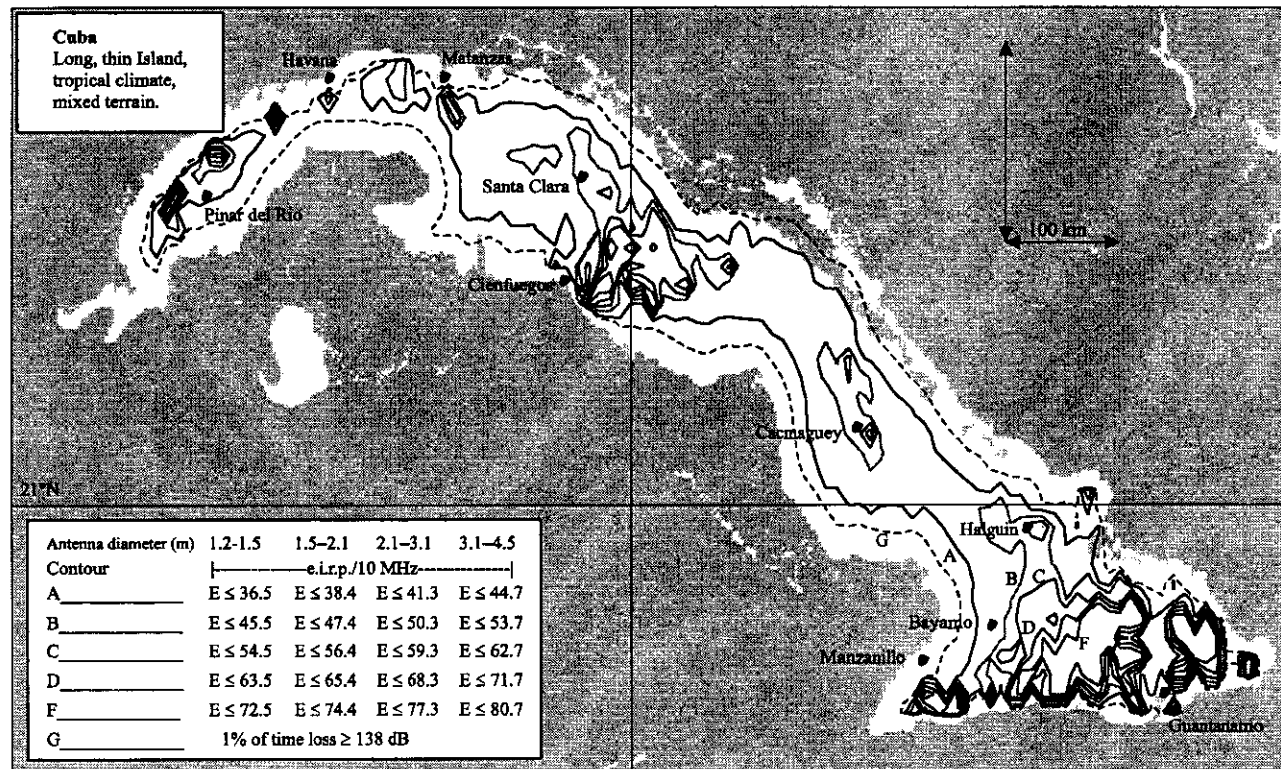


FIGURE 13

Contours beyond which earth stations without shielding would meet  $\text{pfd} = -115 \text{ dB(W/(m}^2 \cdot 10 \text{ MHz))}$  at coast for 99% of time



80°W

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## Annex 3

**Method 3: Method to check compliance of an FSS earth station  
with  
the pfd limits of RR No. 5.502 based on site-specific analysis**

**1 General**

The basis of this method is to perform a site-specific analysis for each FSS earth station to be deployed. Deployment may go forward if the analysis shows that the earth station can meet the pfd limits criteria of RR No. 5.502. The analysis is accomplished by using digital terrain data in conjunction with the FSS earth station parameters, appropriate propagation models and any other attenuation due to natural or manmade shielding. It is expected that Method 3 will only be employed when a potential deployment site cannot be shown to be compliant with the pfd limits using either Method 1 or Method 2.

**2 A description of Method 3**

*Step 1:* Digital terrain data that includes the earth station site and surrounding area is required. The data should encompass a sufficient area to reasonably perform the pfd analysis. It is recommended that the resolution of the digital terrain data used is at least 30 arc/s horizontally and 1 m vertically (e.g. GTOPO30 or GLOBE). If a higher resolution model is available for the administration concerned, its use is encouraged.

*Step 2:* The parameters of the FSS earth station to be deployed will be required for the analysis. This includes the earth station's antenna size, height above terrain, carrier spectral density, and GSO satellite assignment(s). The appropriate reference earth station radiation pattern for this method could be the one provided by the earth station operator or the one found in the relevant ITU-R Recommendations. Note that if it is envisaged that the earth station may have widely different pointing directions, whether because it may be reassigned at some future time or if an alternate GSO satellite is needed during the initial deployment, then the site-specific analysis will need to be performed for each of these pointing directions.

*Step 3:* As with the first two methods, the propagation model best suited to the site-specific analysis is Recommendation ITU-R P.452-11.

*Step 4:* The FSS earth station parameters, digital terrain data, and propagation models enable calculation of the path loss in all direction around the potential site. This in turn yields the pfd at the low-water mark or neighbouring country's land border produced by the station. If the pfd limits criteria of RR No. 5.502 are met, then deployment may proceed. Otherwise, additional interference mitigation techniques may need to be applied. It should be noted that in some locations,

particularly those within direct LoS of the low-water mark or land border, deployment may be difficult. Extra attenuation accrued by natural or man-made site-shielding can be applied to this method. The determination of the precise level of attenuation from site-shielding will require further study with a combination of analysis using the above models.

*Step 5:* A site survey measuring the horizon profile around the earth station from which the actual attenuation from local site-shielding and actual terrain could be derived and applied in the calculations to determine the pfd at the low-water mark or land border produced by the station.

#### Annex 4

**Additional considerations for small and narrow countries to meet the criteria of RR No. 5.502 and/or as a basis for the establishment of bilateral agreements to exceed the limits of RR No. 5.502**

##### **1 General**

If a country is geographically small or narrow, contours based on the Methods 1 and 2 (Annexes 1 and 2) may exclude the majority of the territory. Resolution 144 (WRC-03) resolves that the administrations of geographically small or narrow countries may exceed the limitations on FSS earth station power flux-density at the low-water mark in No. 5.502 if such operation is in conformance with bilateral agreements with administrations deploying maritime radiolocation systems in the band 13.75-14 GHz.

The following sections introduce measures that all administrations can take to help meet the requirements of RR No. 5.502. These same considerations might be taken into account in bilateral discussions concerning small or narrow countries. Since circumstances differ widely from country to country, no attempt to generalize is made here. It is advisable for each case to be considered on its merits in order to decide which of the possibilities to take into account, and to what extent they are applicable.

##### **2 Restrict operation in the 13.75-14 GHz band to medium or low e.i.r.p. carriers**

Table 4 may be used to determine the reduction in maximum e.i.r.p. achievable by restricting the proportion of 14 GHz band carriers in comparison with those currently operated in the 14-14.5 GHz band. To obtain these results the available data were used to compile cumulative distributions giving percentage of earth stations-vs.-e.i.r.p./10 MHz for each of the four ranges of antenna size. Thus, for example, by foregoing the opportunity to deploy the 20% of earth stations with antenna diameters between 1.2 m and 1.5 m that would transmit e.i.r.p. levels at the high end of

*the range, all other earth stations could be operated up to a contour corresponding to 9 dB lower minimum path-loss to the border, without exceeding the pfd limit anywhere on the border.*

TABLE 4

Reductions in maximum e.i.r.p./in 10 MHz-restrictions – restrictions  
in proportion of carriers

Antenna diameter range	Reduction in proportion of carriers			
	100% to 80%	80% to 60%	60% to 40%	40% to 20%
$1.2 \text{ m} \leq D < 1.5 \text{ m}$	$55 - 46 = 9 \text{ dB}$	$46 - 42 = 4 \text{ dB}$	$42 - 39 = 3 \text{ dB}$	$39 - (-2) = 41 \text{ dB}$
$1.5 \text{ m} \leq D < 2.1 \text{ m}$	$70 - 49 = 21 \text{ dB}$	$49 - 47 = 2 \text{ dB}$	$47 - 47 = 0 \text{ dB}$	$47 - 43 = 4 \text{ dB}$
$2.1 \text{ m} \leq D < 3.1 \text{ m}$	$85 - 61 = 24 \text{ dB}$	$61 - 52 = 9 \text{ dB}$	$52 - 52 = 0 \text{ dB}$	$52 - 52 = 0 \text{ dB}$
$3.1 \text{ m} \leq D < 4.5 \text{ m}$	$95 - 71 = 24 \text{ dB}$	$71 - 63 = 8 \text{ dB}$	$63 - 56 = 7 \text{ dB}$	$56 - 47 = 9 \text{ dB}$

If a given reduction in the proportion of earth stations in a particular antenna size range that would otherwise be operable between 13.75 GHz and 14 GHz could be accepted, the corresponding reduction in maximum e.i.r.p. could be determined in this way, and the relevant contour computed as described in Annex 2. That contour would encompass more of the small country concerned than if the constraint had not been accepted.

### 3 Apply local site-shielding to earth stations

It is possible to reduce the maximum interference produced at the low-water mark or neighbouring country's land border by any earth station within a country by the addition of shielding attenuation to the site of that earth station. This may be done either by locating the antenna behind a building or other obstacle in the direction of the closest point at which the pfd has to be met, or by the addition of a shield of attenuating material on that side. Since the practicality and/or cost-effectiveness of such measures depends on circumstances, their feasibility can only be assessed on a case-by-case basis. Although shielding in front of an antenna will reduce the interference toward the horizon, the benefit can be offset by signal enhancement due to reflections from buildings or other objects in the vicinity of the antenna. Furthermore, it is difficult to derive worthwhile shielding if the antenna operates at relatively low elevation and the nearest part of the border lies generally in the direction of the Equator. Another factor is that the cost associated with either locating behind a building or adding an artificial shield may increase the cost of a small-dish terminal by a significant percentage.

ITU-R reviewed the shielding and "clutter" attenuations calculated using the empirical algorithms in Recommendations ITU-R P.452 and ITU-R P.526, and compared them with the results of measurements reported in the United Kingdom in 1995. The provisional conclusion of the ITU-R was that, in cases where it is practicable, the attenuation available from site-shielding will usually be between 5 dB and 20 dB depending on circumstances, and is unlikely to exceed 25 dB. More work is needed to confirm this conclusion and expand on the possibilities of site-shielding.

Once the degree of site-shielding attenuation ( $A$  dB) available for a specific site has been estimated, and the methodology in Annex 2 has been used to find the magnitude and direction of the minimum loss,  $L$ , to the border, equation (2) rearranged and including  $A$  can be used to determine the maximum e.i.r.p./10 MHz which an earth station at the site could transmit without exceeding the RR No. 5.502 pfd limit, i.e.  $E = L + A + (G_m - G(\phi)) - 159.29$  dBW.

#### 4 Selection of earth station antenna diameter

If the attenuation in the direction of the lowest-loss path to the low-water mark or neighbouring country's land border is insufficient for the pfd limits to be met by a planned earth station, but only by a modest amount, one possibility might be to use a slightly larger antenna than would otherwise be necessary. This would enable the transmitter power to be reduced by an amount equal to the difference in antenna gain, thus reducing the off-axis e.i.r.p. by the same amount. Since antenna gain is proportional to the square of the diameter,  $D$ , Table 5 gives some changes in  $D$  to compensate for potential exceedences of the pfd limits within the probable range of interest.

TABLE 5

Increases in antenna diameter to compensate for attenuation shortfall

Excess of pfd to be compensated	1 dB				2 dB				3 dB				4 dB			
Baseline antenna diameter (m)	1.2	1.5	1.8	2.1	1.2	1.5	1.8	2.1	1.2	1.5	1.8	2.1	1.2	1.5	1.8	2.1
Substitute antenna diameter (m)	1.35	1.68	2.02	2.36	1.51	1.89	2.27	2.64	1.70	2.12	2.54	2.97	1.90	2.38	2.85	3.33

#### 5 Seek bilateral agreements to exceed the pfd limit

Given that if a country is small, the length of border near which radar terminals in neighbouring countries, or at sea, may be exposed to interference from FSS earth stations within the country is also small, so the overall impact on the radiolocation service may be correspondingly small.



Therefore it may be possible for a small country to conclude for terminals in the 13.75-14 GHz band in that area when the pfd limit is exceeded by up to a specified amount, e.g. 5 dB or 10 dB.

Conceptually it would appear to be possible to reach agreement to relax the time percentage part of the limit, rather than to relax the pfd level – for example to permit  $-115 \text{ dB(W/m}^2\text{)}$  to be exceeded for, say, 5% of the time rather than 1% of the time. However, ITU-R studies revealed that, at least in the case of a medium terrain in a temperate climate, contours for a range of specific path-loss levels change very little if the time percentage is increased above about 0.5% (although they tend to worsen significantly from the FSS viewpoint if the time percentage is reduced below that figure). Hence it seems that in practice, whilst modest increases in pfd level may be worth considering, increasing the time percentage is unlikely to be a worthwhile line for bilateral discussions to pursue.

6 Seek bilateral agreements to waive the pfd limit for part of the band  
If individual mobile radar signals within the 13.75-14 GHz band occupy bandwidths which are significantly less than 250 MHz, it may be possible for a small country to restrict its FSS use to part of the band, and for another administration to use only the remainder of the band for its mobile radar terminals while they are in the vicinity of the small country. This would be a form of limited band-segmentation.

During the statistical analysis of the available data it was noted that the majority of 14 GHz band earth stations with antennas in the 1.2-4.5 m diameter range transmit single carriers having bandwidths less than 10 MHz, and that very few operate carriers having bandwidths greater than 36 MHz. The criterion used in Radiocommunication Study Group 8 for the protection of 14 GHz band radar terminals is an  $J/N$  ratio of  $-6 \text{ dB}$  in a bandwidth of 10 MHz, and this suggests that the bandwidths of typical radar signals in the band 13.75-14 GHz are of the order of 10 MHz. Hence there appears to be scope for bilateral agreements based on band segmentation, although this might be regarded as a last resort since it would reduce the amount of spectrum available to both services, albeit only in and around small countries. However, RR No. 5.503 must be kept in mind when considering band-segmentation options.

## APPENDIX B

### Proposed modifications to FCC Rules

Comment:

## APPENDIX B

### Proposed modifications to FCC Rules

The following are proposed texts for modifications to the referenced FCC rules:

#### A. Part 2.106

1. In the International and U.S.domestic Table of Frequency, In the band 13.75-14.00 GHz, SUPPRESS footnote No. 5.503A;

2. In the list of INTERNATIONAL FOOTNOTES, replace the text for No. 5.502, and No. 5.503 with the text in the same numbered footnotes which was adopted at WRC-03 to which the U.S is signatory and which has come into force as international law for several years;

3. Modify US 356 to conform with the results of WRC-03 as follows:

In the band 13.75-14.00 GHz, an earth station of a geostationary fixed satellite service network shall have a minimum antenna diameter of 1.2 m and an earth station of a non-geostationary fixed-satellite service system shall have a minimum antenna diameter of 4.5 m. In addition the e.i.r.p. averaged over one second, radiated by a station in the radiolocation or radionavigation services shall not exceed 59 dBW for elevation angles above 2 degrees and 65 dBW at lower angles. Before an administration brings into use an earth station in a geostationary-satellite network in the fixed satellite service in this band with an antenna size smaller than 4.5 m, it shall ensure that the power flux density produced by this earth station does not exceed [(See ITU-R Recommendation SF. 1712)]:

- 115 dB (W/ (m<sup>2</sup>. 10 MHz)) for more than 1% of the time produced at the low water mark, as officially recognized by the coastal state.
- 115 dB/ (m<sup>2</sup>. 10 MHz)) for more that 1 % of the time produced 3m above ground at the border of the territory of administration deploying or planning to deploy land mobile radars in this band, unless prior agreement has been obtained.

For earth stations within the fixed satellite service having an antenna diameter greater than or equal to 4.5m, the e.i.r.p. of any emission should be at least 68 dBW and should not exceed 85 dBW.

4. Modify footnote US 357 to reflect the results of WRC-03 as follows:

In the band 13.75-14.0 GHz geostationary space stations in the space research service for which information for advance publication has been received by the ITU Radiocommunication Bureau (Bureau) prior to 31 January 1992 shall operate on a secondary basis with stations in the fixed satellite service: after that date, new geostationary space stations in the space research service will operate on a secondary basis. Until those space stations in the space research service for which information for advance publication has been received by the Bureau prior to 31 January 1992 cease to operate in this band:

a. The e.i.r.p. density in the band 13.77-13.78 GHz of emissions from any earth station in the fixed-satellite service operating with a space station in geostationary-satellite orbit shall not exceed:

- i)  $4.7D + 28$  dB (W/40kHz), where D is the fixed satellite earth station antenna diameter (m) for antenna diameters equal to or greater than 1.2m and less than 4.5m.
- ii)  $49.2 + 20 \log (D/4.5)$  dB (W/40 kHz), where D is the fixed satellite service earth station diameter(m) for antenna diameters equal to or greater than 4.5 m and less than 31.9m.
- iii) 66.2 dB (W/40/kHz) for any fixed satellite service earth station antenna diameter(s) greater than 39.1 m.
- iv) 56.2 dB (W/40/kHz) for narrow band (less than 40 kHz) of necessary bandwidth) fixed satellite earth station emissions from any fixed satellite earth station having an antenna of 4.5 m or greater.

b. The e.i.r.p. density of emissions from any earth station in the fixed satellite service operating with a space station in non-geostationary-satellite orbit shall not exceed 51 dBW in any 6 MHz band from 13.77-13.78 GHz.

Automatic power control may be used to increase the e.i.r.p. density in these frequency ranges to compensate for rain attenuation, to the extent that the power flux-density at the fixed satellite service space station does not exceed the value resulting from use by an earth station of an e.i.r.p. meeting the above limits in clear air conditions (WRC-03).

## B. Part 25 Satellite Communications

### 1. Section 25.134

Add a new section (e) to section 25.134 as follows:

(e) V sat networks operating in the 12/13.75-14.0 GHz bands  
All applications for digital and analogue V sat networks using the band 13.75-14.0 GHz shall be processed routinely in accordance with the provisions of (a) and (b) above provided they meet the requirements of No. US356 and US357 (as modified). Reference to 14 GHz bands is understood to include the band 13.75-14.0 GHz. The requirements of US 357 and US 358 are considered to be met if the earth station antenna meets the coastal separation conditions specified for the earth station antenna size and associated e.i.r.p.[ see graph XYZ].

### 2. Section 25.208

Add a new section (u) to section 25.208 as follows:

(u) In the band 13.75-14.00 GHz for earth stations with antenna diameters smaller than 4.5m, the calculation of the pfd limits specified in US356 and US357 (as modified) shall be performed in accordance with the provisions of ITU-R Recommendation S. 1712.

### 3. Section 25.115

Add a new section (g) to section 25.115 as follows:

(g) FSS earth stations in the band 13.75-14.00 GHz operating with U.S. licensed or non-U.S. licensed geostationary satellites which have antennas no smaller than 4.5 m shall be processed routinely.

4. Add a new section (h) to Part 25.204

(h) FSS earth stations operating in the band 13.75-14.0 GHz having antennas from 1.2 m to 4.5 m need to meet the coastal separation distance for the e.i.r.p specified in graph XYZ (to be developed based on Recommendation ITU-R S. 1712, and agreed with NTIA) to be routinely process. If the distance is not met then the earth station will be individually process.